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WHAT IS CLAIMED IS:

1. A fluidized bed reactor for use in removing solutes from wastewater, the reactor comprising
 - 5 a column comprising a substantially vertically oriented conduit having a harvesting section and at least two vertically sequential sections located above the harvesting section, a cross sectional area of the conduit increasing between adjacent ones of the sections;
 - 10 an inlet for wastewater in the column in or below the harvesting section; and,
 - a recycling path extending from an outlet in an upper portion of the conduit to the inlet.
- 15 2. A fluidized bed reactor according to claim 1 wherein the cross sectional area of the conduit increases stepwise between the adjacent ones of the sections.
- 20 3. A fluidized bed reactor according to claim 2 wherein the inlet is oriented substantially vertically and is configured to direct a turbulent jet of influent wastewater upward into the column.
4. A fluidized bed reactor according to claim 3 comprising a pH sensor located in the harvesting section above a mixing zone.
- 25 5. A fluidized bed reactor according to claim 4 comprising a pH control system connected to receive a signal from the pH sensor,

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the pH control system connected to control a metering mechanism configured to introduce an alkaline substance into the column below the pH sensor in response to a pH control input from the pH controller.

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6. A fluidized bed reactor according to claim 5 wherein the pH controller is configured to control the pH at the pH sensor to a value in the range of 7.4 to 8.5.

- 10 7. A fluidized bed reactor according to claim 5 wherein the pH controller is configured to control the pH at the pH sensor to a value of less than 8.

- 15 8. A fluidized bed reactor according to claim 1 wherein a ratio of a cross sectional area of a topmost one of the sections to a cross sectional area of the harvesting section is at least 10:1.

- 20 9. A fluidized bed reactor according to claim 2 wherein a ratio of a cross sectional area of a topmost one of the sections to a cross sectional area of the harvesting section is at least 10:1.

10. A fluidized bed reactor according to claim 9 wherein the ratio of the cross sectional area of the topmost section to the cross sectional area of the harvesting section exceeds 20:1.

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11. A fluidized bed reactor according to claim 8 wherein the ratio of the cross sectional area of the topmost section to the cross sectional area of the harvesting section exceeds 20:1.
- 5 12. A fluidized bed reactor according to claim 10 wherein the cross sectional area of the conduit increases stepwise by a factor of at least $1\frac{1}{2}$ between the adjacent ones of the sections.
- 10 13. A fluidized bed reactor according to claim 8 wherein the cross sectional area of the conduit increases stepwise by a factor of at least $1\frac{1}{2}$ between the adjacent ones of the sections.
14. A fluidized bed reactor according to claim 1 comprising a clarifier located in the recycling path.
- 15 15. A fluidized bed reactor according to claim 1 comprising an air stripper located in the recycling path.
16. A fluidized bed reactor according to claim 1 comprising an air
20 stripper located in an air stripper path separate from the recycling path.
17. A fluidized bed reactor according to claim 1 comprising a
25 supersaturation controller configured to control a supersaturation ratio for struvite, a struvite analog, or a phosphate compound within the harvesting section by, at least in part, controlling a recycling ratio of a rate at which wastewater is being introduced.

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into the column by way of the recycling path to a total rate at which wastewater is being introduced into the column.

18. A fluidized bed reactor according to claim 17 wherein the
5 supersaturation controller is configured to control the
 supersaturation ratio to have a value between 2 and 5.
19. A fluidized bed reactor according to claim 17 wherein the
10 supersaturation controller is configured to control the
 supersaturation ratio to have a value between 3 and 4.
20. A fluidized bed reactor according to claim 17 wherein the
 supersaturation controller is connected to control a metering
 mechanism configured to introduce a cation-containing solution
15 into the column in response to a cation control input from the
 supersaturation controller.
21. A fluidized bed reactor according to claim 16 wherein the
 supersaturation controller is connected to control a metering
20 mechanism configured to introduce a cation-containing solution
 into the column in response to a cation control input from the
 supersaturation controller.
22. A fluidized bed reactor according to claim 16 wherein the
25 supersaturation controller is connected to control a metering
 mechanism configured to introduce an ammonia-containing

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solution into the column in response to a ammonia control input from the supersaturation controller.

23. A fluidized bed reactor according to claim 16 comprising a flow
5 controller connected to control the total rate at which wastewater is
being introduced into the column to have a value such that an
average upward fluid velocity within the harvesting section is at
least 400 cm/min.
- 10 24. A fluidized bed reactor according to claim 1 comprising an
isolation valve located in the column to isolate at least a major
portion of the harvesting section.
- 15 25. A fluidized bed reactor according to claim 24 comprising a bypass
conduit connected to direct fluid from the input to a location in the
column above the isolation valve when the isolation valve is
closed.
- 20 26. A fluidized bed reactor according to claim 1 wherein the at least
two vertically sequential sections above the harvesting section
comprise three or more sections.
- 25 27. A fluidized bed reactor according to claim 2 wherein the at least
two vertically sequential sections above the harvesting section
comprise three or more sections.

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28. A fluidized bed reactor according to claim 27 wherein the cross sectional area of the conduit increases stepwise by a factor of at least $1\frac{1}{2}$ between the adjacent ones of the sections.
- 5 29. A fluidized bed reactor according to claim 1 wherein the cross sectional area of the conduit increases stepwise by a factor of at least 5 between a next-to-topmost one of the sections and a topmost one of the sections.
- 10 30. A fluidized bed reactor according to claim 1 wherein the column has a height of at least 5 meters.
31. A fluidized bed reactor according to claim 1 wherein the sections of the column are round in cross section.
- 15 32. A fluidized bed reactor according to claim 1 wherein the conduit has step-like transitions between the adjacent ones of the sections.
33. A method for extracting one or both of phosphorus and nitrogen from wastewater, the method comprising:
- 20 introducing the wastewater into a column comprising a substantially vertically oriented conduit having a harvesting section and at least two vertically sequential sections above the harvesting section, wherein a cross sectional area of the conduit
- 25 increases between adjacent ones of the sections;

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maintaining supersaturation conditions for struvite, a struvite analog, or a phosphate compound in the harvesting section;

recycling wastewater which has passed through the column while controlling a supersaturation ratio of struvite, a struvite analog, or a phosphate compound in the harvesting section at least in part by controlling a recycling ratio of a rate at which wastewater is recycled into the column to a total rate at which wastewater is being introduced into the column; and,

extracting from the harvesting section pellets formed within the column .

34. A method according to claim 33 wherein the cross sectional area of the conduit increases stepwise between adjacent ones of the sections.

35. A method according to claim 34 wherein the cross sectional area of the conduit increases stepwise by a factor of at least $1\frac{1}{2}$ between the adjacent ones of the sections.

36. A method according to claim 33 wherein maintaining supersaturation conditions comprises maintaining a supersaturation ratio in the range of 2 to 5 within the harvesting section.

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37. A method according to claim 36 wherein maintaining supersaturation conditions comprises maintaining a pH in the range of 7.4 to 8.5 within the harvesting section.
- 5 38. A method according to claim 36 wherein maintaining supersaturation conditions comprises maintaining a pH not exceeding 8 in the harvesting section.
- 10 39. A method according to claim 33 wherein maintaining supersaturation conditions comprises maintaining a supersaturation ratio in the range of 3 to 4 within the harvesting section.
- 15 40. A method according to claim 33 wherein the pellets comprise pellets of struvite.
41. A method according to claim 33 wherein the pellets comprise pellets of a struvite analog.
- 20 42. A method according to claim 41 wherein the struvite analog is potassium magnesium phosphate.
- 25 43. A method according to claim 33 wherein maintaining supersaturation conditions comprises controllably introducing a cation solution into the column.

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44. A method according to claim 43 wherein the cation solution comprises magnesium ions.
- 5 45. A method according to claim 33 comprising maintaining concentrations of magnesium and ammonia higher than a concentration of phosphate within the harvesting section.
- 10 46. A method according to claim 33 comprising maintaining concentrations of magnesium and phosphate higher than a concentration of ammonia within the harvesting section.
47. A method according to claim 45 comprising adding a ammonia solution to the column.
- 15 48. A method according to claim 35 comprising maintaining an average upward flow velocity of at least 400 cm/min within the harvesting section.
- 20 49. A method according to claim 48 comprising maintaining an average upward flow velocity not exceeding 75 cm/min within an uppermost one of the sections.
- 25 50. A method according to claim 48 comprising maintaining a ratio of the average upward flow velocity in the harvesting section to the average upward flow velocity in the uppermost section to be at least 10:1.

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51. A method according to claim 50 comprising maintaining the ratio of the average upward flow velocity in the harvesting section to the average upward flow velocity in the uppermost section to be at least 20:1.
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52. A method according to claim 33 comprising maintaining an average upward flow velocity of at least 400 cm/min within the harvesting section.
- 10 53. A method according to claim 52 comprising maintaining an average upward flow velocity not exceeding 75 cm/min within an uppermost one of the sections.
- 15 54. A method according to claim 53 comprising maintaining a ratio of the average upward flow velocity in the harvesting section to the average upward flow velocity in the uppermost section to be at least 10:1.
- 20 55. A method according to claim 35 wherein recycling wastewater which has passed through the column comprises passing the wastewater through a clarifier before reintroducing the wastewater into the column.
- 25 56. A method according to claim 33 wherein recycling wastewater which has passed through the column comprises passing the wastewater through an air stripper before reintroducing the wastewater into the column.

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57. A method according to claim 33 wherein extracting from the harvesting section pellets formed within the column comprises extracting the pellets at a rate such that a crystal retention time of pellets in the column is at least one week.

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58. A method according to claim 33 wherein extracting from the harvesting section pellets formed within the column comprises extracting the pellets at a rate such that a crystal retention time of pellets in the column is at least four days.

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59. A method according to claim 33 wherein extracting from the harvesting section pellets formed within the column comprises extracting the pellets at a rate such that a crystal retention time of pellets in the column is in the range of 8 to 12 days.

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60. A method for extracting one or both of phosphorus and nitrogen from wastewater, the method comprising:

maintaining supersaturation conditions for a solid reaction product in a substantially vertically oriented column;

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introducing the wastewater into column and allowing particles of the reaction product to form in the column;

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maintaining the particles of the reaction product in a fluidized bed within the column, the fluidized bed spanning at least three vertically sequential zones within the column, wherein wastewater within each of the zones has a different average upward fluid velocity and the average upward fluid velocity is less

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in vertically higher ones of the zones than in vertically lower ones of the zones;

allowing particles to grow to a size sufficient to migrate downward to a harvesting zone comprising at least a portion of a lowermost one of the at least three zones; and,

harvesting particles from the harvesting zone.

61. A method according to claim 60 wherein the reaction product comprises struvite.

62. A method according to claim 60 wherein the reaction product comprises a struvite analog.

63. A method according to claim 62 wherein the struvite analog is potassium magnesium phosphate.

64. A method according to claim 60 comprising maintaining an average upward flow velocity of at least 400 cm/min within the harvesting zone.

65. A method according to claim 64 comprising maintaining an average upward flow velocity not exceeding 75 cm/min within an uppermost one of the zones.

66. A method according to claim 65 comprising maintaining a ratio of the average upward flow velocity in the harvesting zone to the

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average upward flow velocity in the uppermost zone to be at least 10:1.

- 5 67. A method according to claim 65 comprising maintaining the ratio of the average upward flow velocity in the harvesting zone to the average upward flow velocity in the uppermost zone to be at least 20:1.